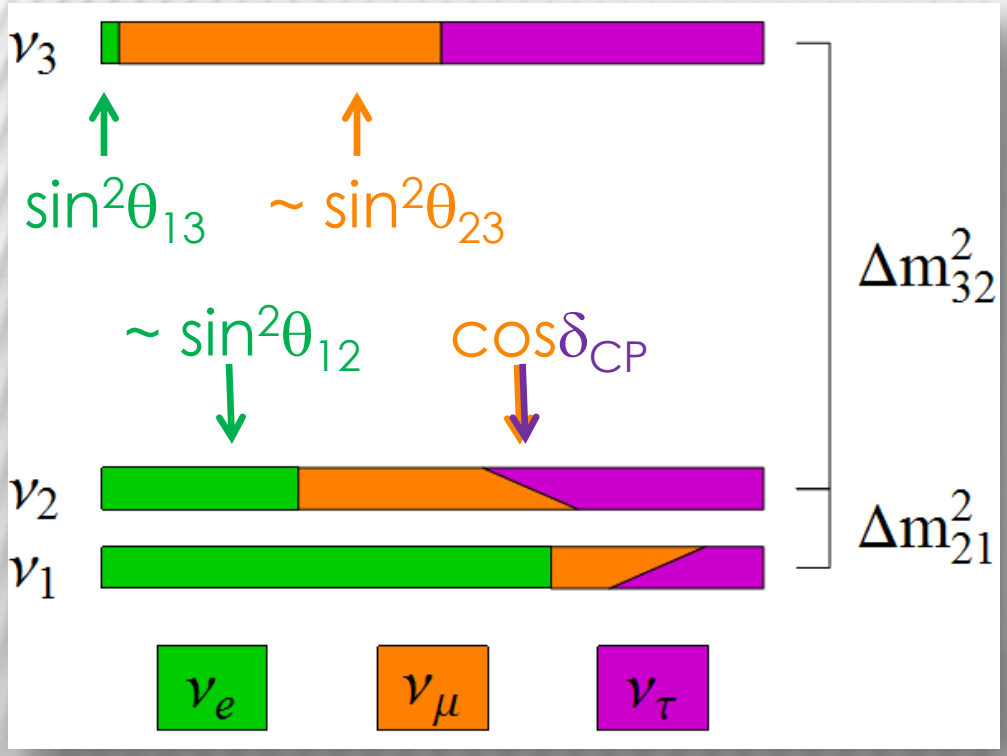
Joao Coelho
For the CHIPS Collaboration

STATUS OF CHIPS

NEUTRINO OSCILLATION

- 3 mixing angles (θ_{12}, θ_{13}, θ_{23}) and 1 phase δ_{CP}
- δ_{CP} creates difference between ν and $\bar{\nu}$ (CP violation). **Currently unknown.** (Some hints)



Simple QM

$$|\nu_\alpha\rangle = \sum_i U_{\alpha i} |\nu_i\rangle$$

$$P(\nu_\alpha \to \nu_\beta) = \left|\langle \nu_\beta | e^{-iHt} | \nu_\alpha \rangle\right|^2$$

$$H.t \sim \Delta E.L \sim \frac{\Delta m^2 L}{2E}$$

NEUTRINO OSCILLATION

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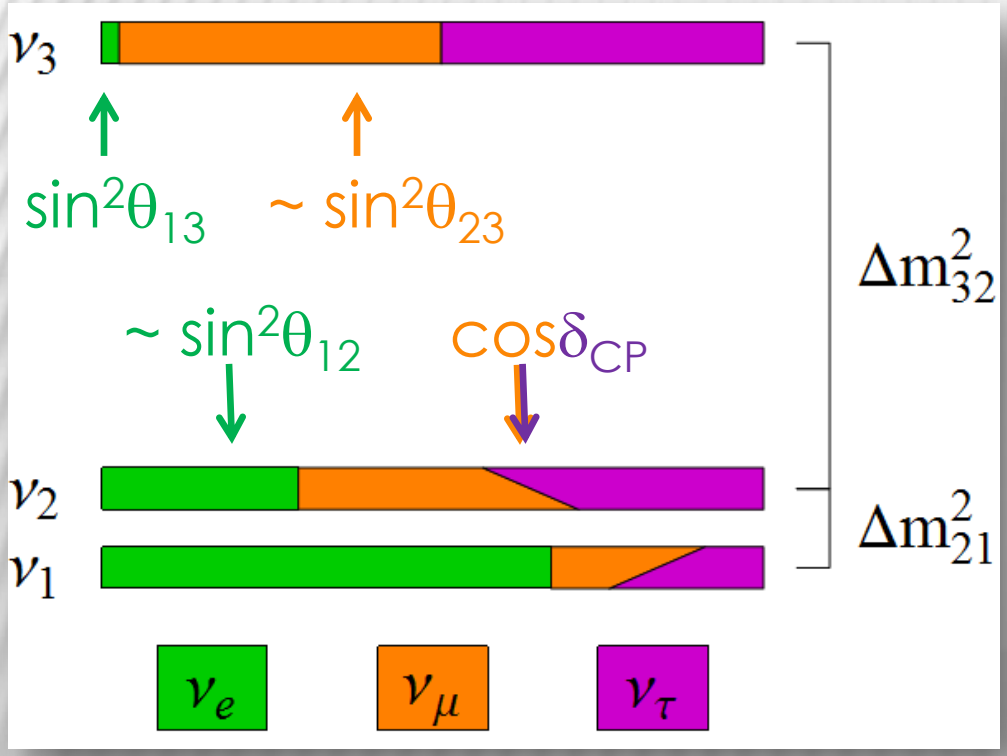

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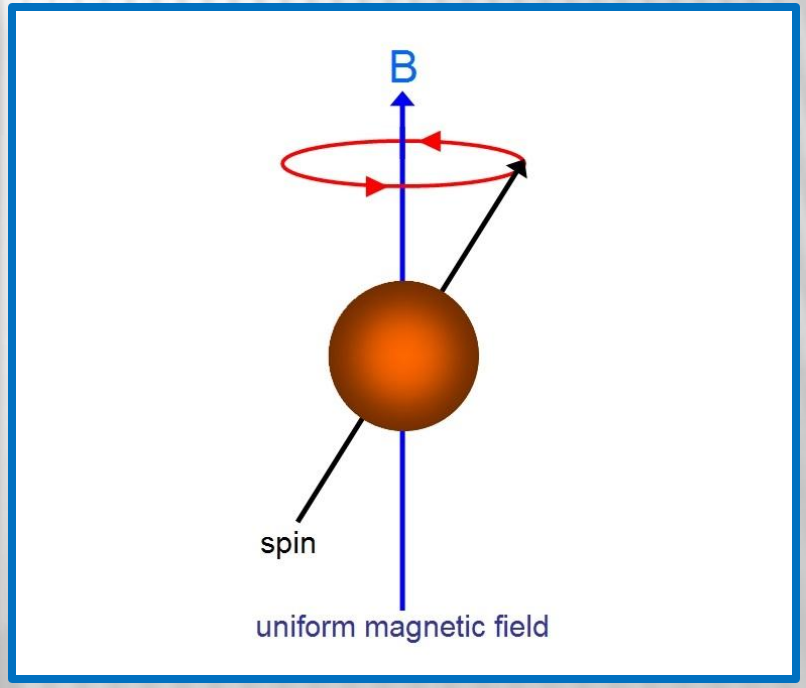

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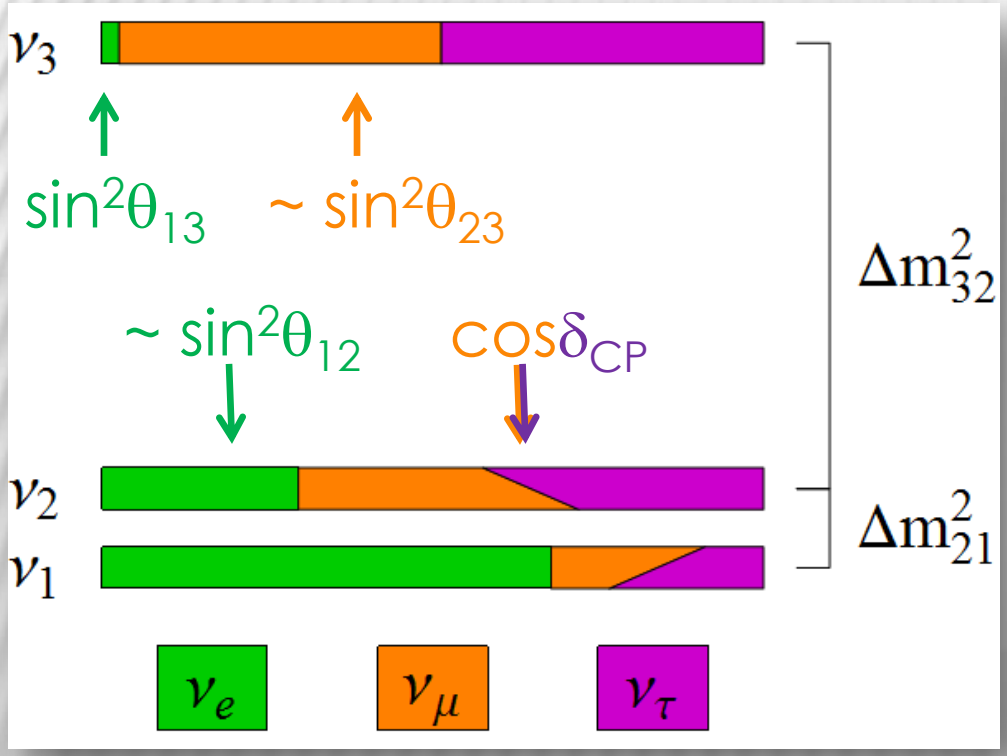

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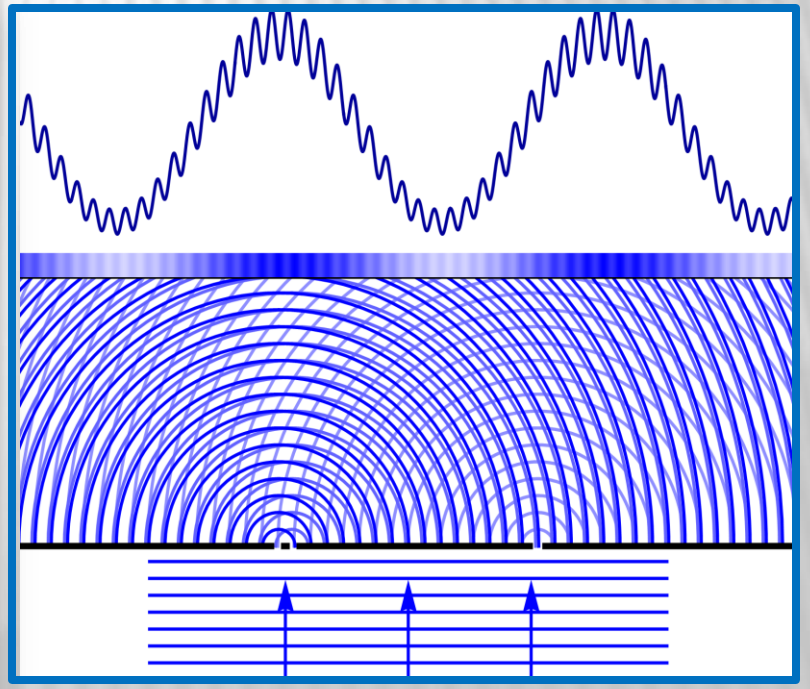
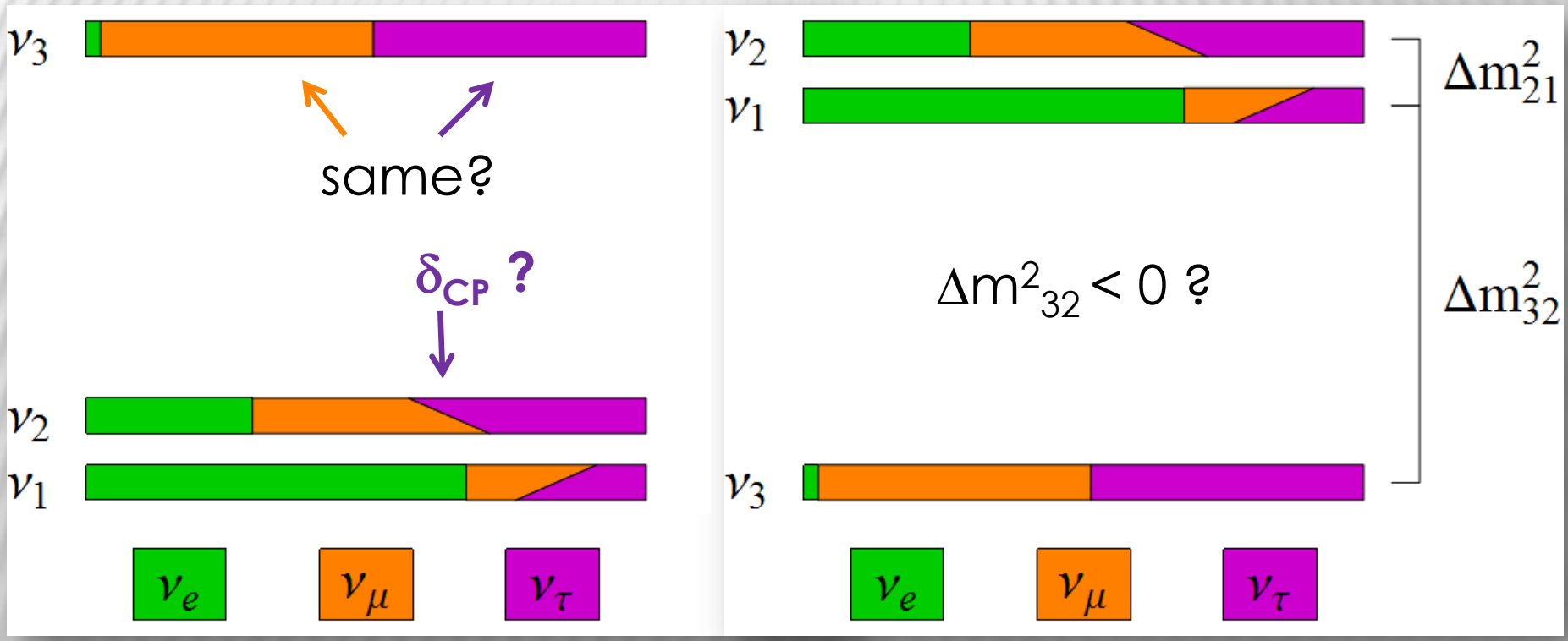


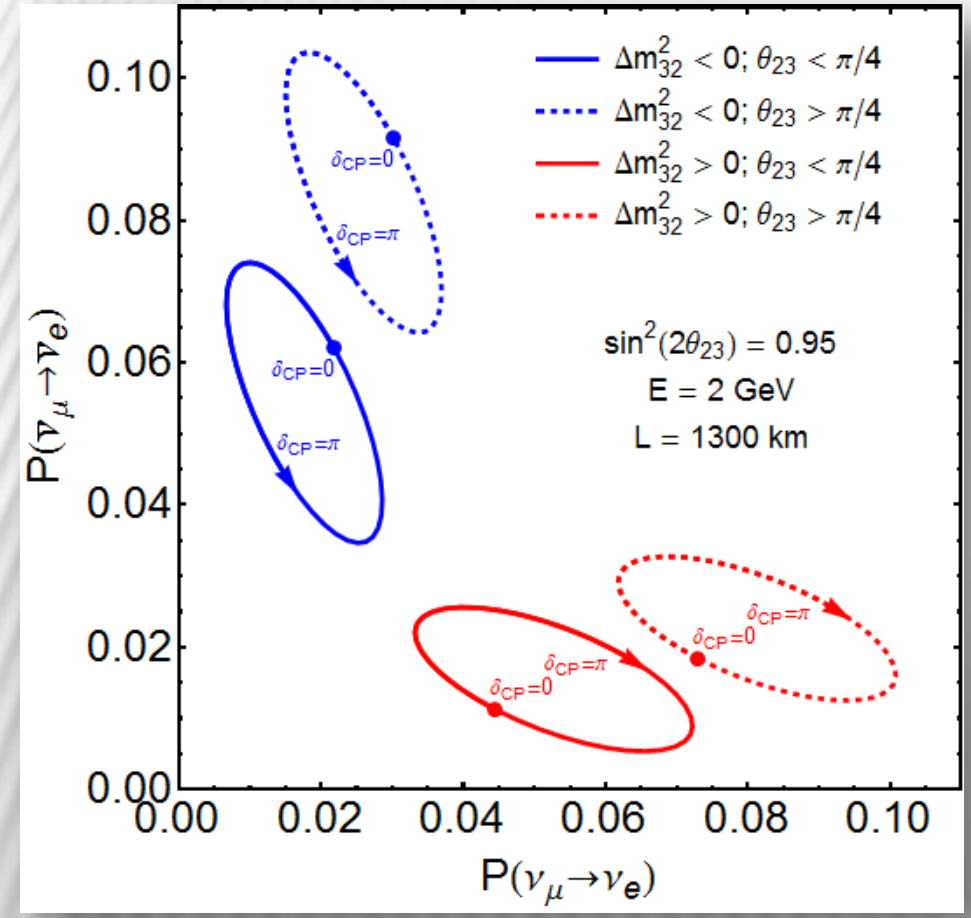
MISSING PIECES

- Do neutrinos and antineutrinos oscillate the same? (δ_{CP})
- What is the mass ordering? (Mass Hierarchy)
- Is $\theta_{23} = \pi/4$? Underlying symmetry?



THE POWER OF NUE APPEARANCE

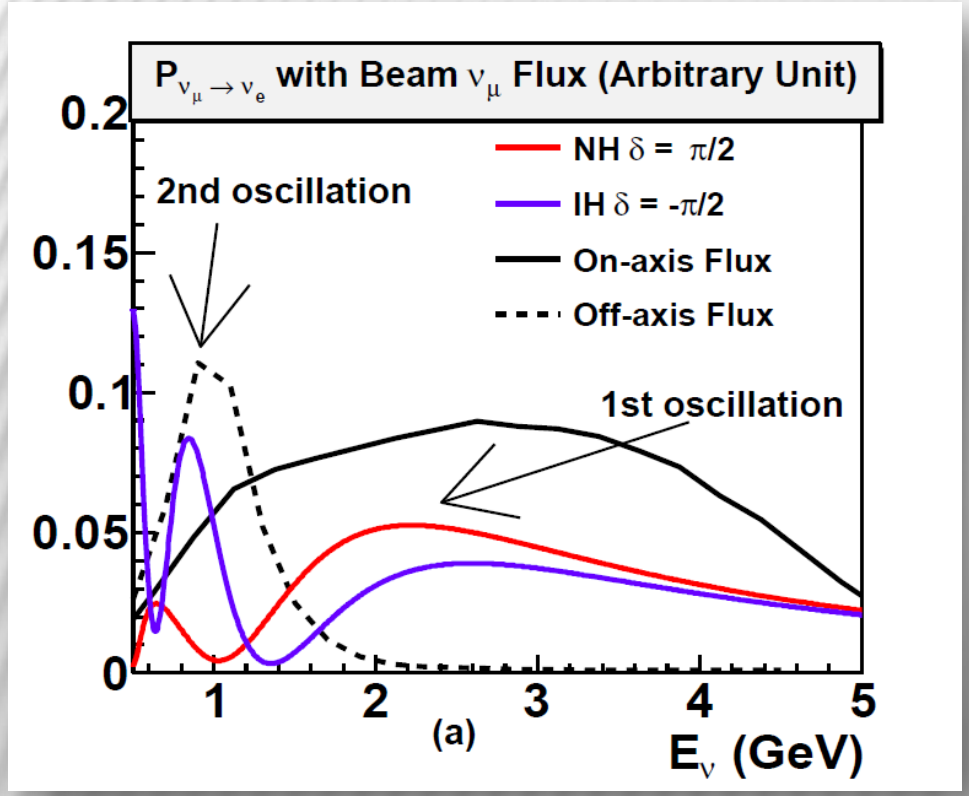
DUNE

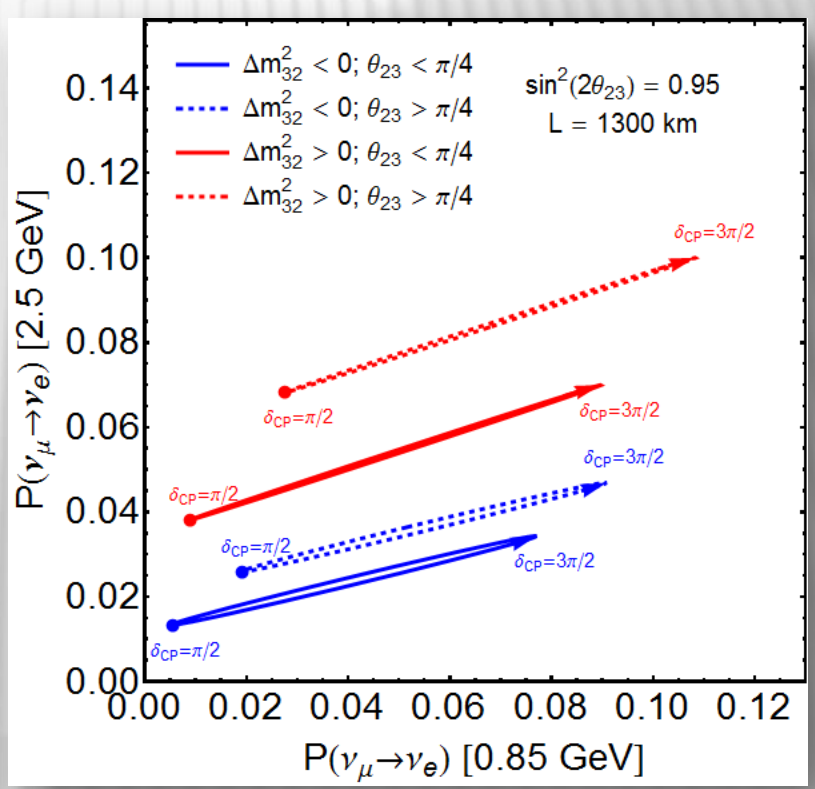


- Tease apart degenerate solutions
- Measure all remaining parameters
- Works best with multiple baselines and energies

COMPLEMENTARY

- Comparison between ν_e rates at 1st and 2nd max.
- Significant extra power to resolve degeneracies



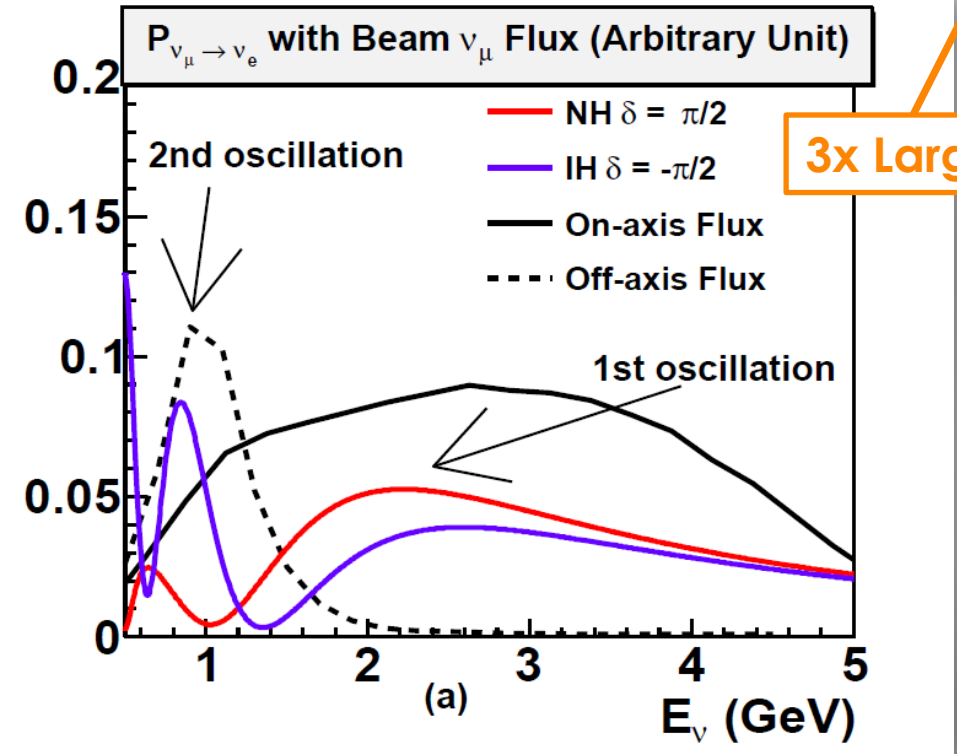


CPV ← • → CPV

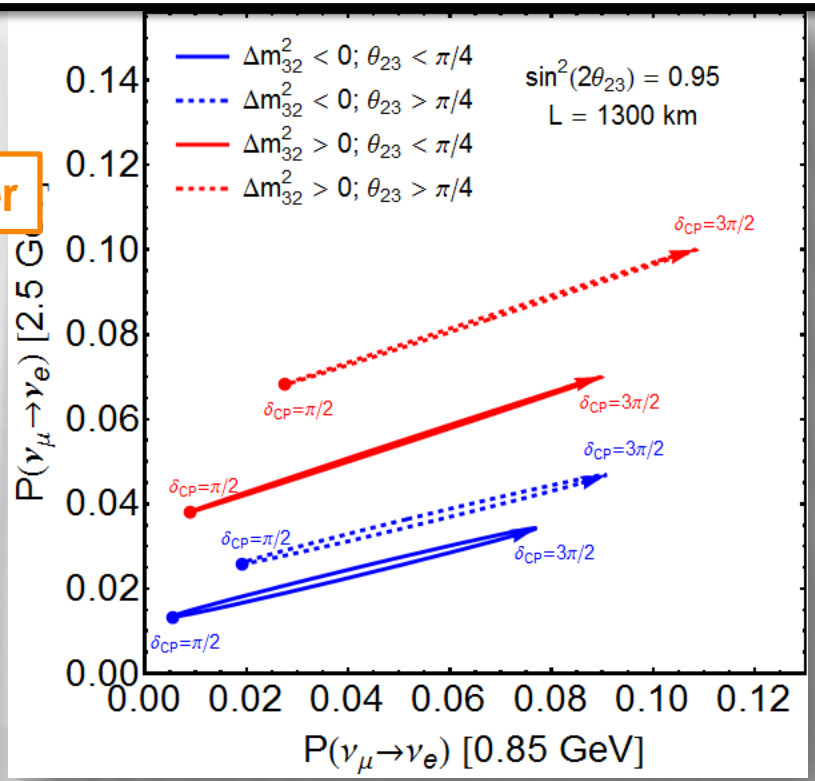
No CPV

COMPLEMENTARY

$$\mathcal{P}(\nu_\mu \to \nu_e) \approx \sin^2\theta_{23}\sin^2(2\theta_{13})\sin^2\Delta_{\mu e} \pm \tilde{J}\sin\delta\sin\Delta_{21}\sin^2\Delta_{\mu e} + \mathcal{O}(\Delta_{21})^2$$



3x Larger

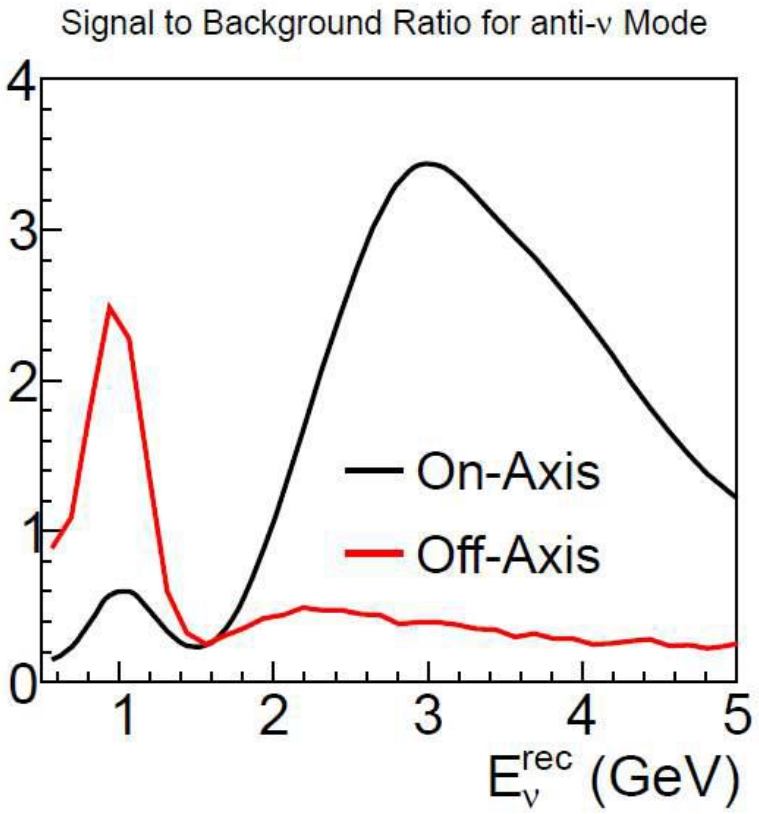


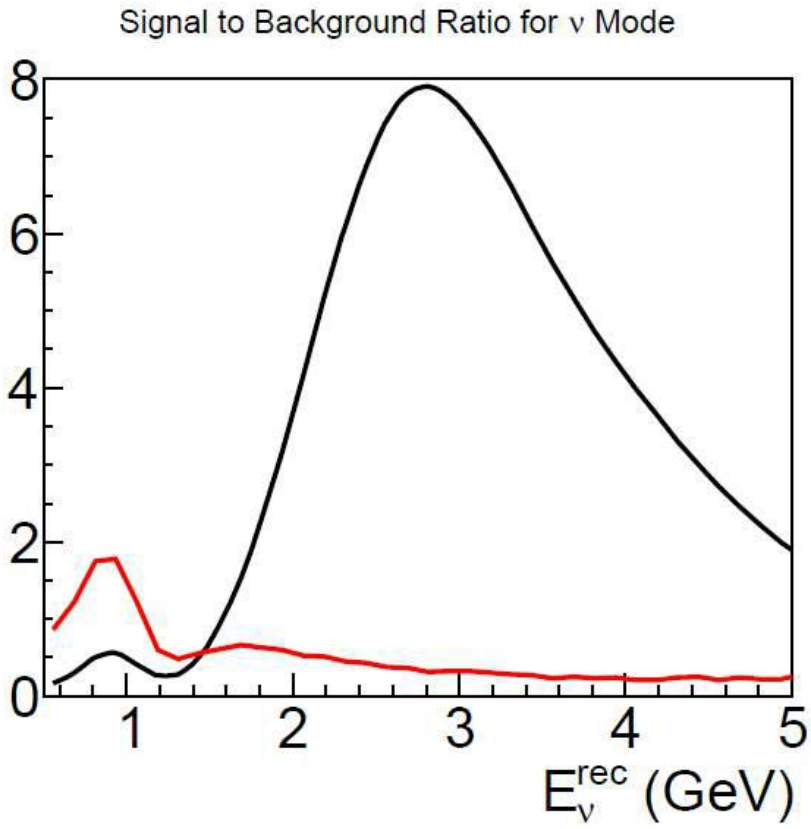
CPV ← • → CPV

No CPV

COMPLEMENTARY

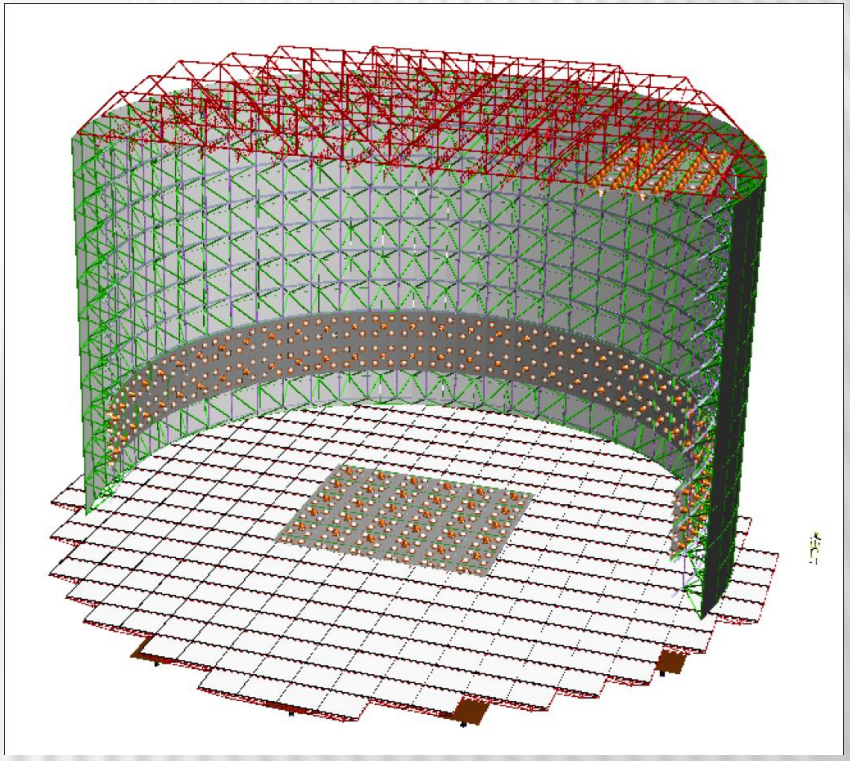
- Off-axis WC detector has better sig/bkg for 2nd max.

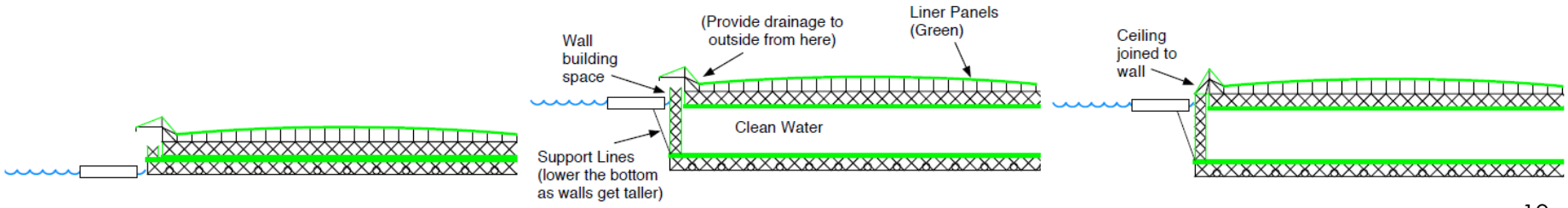




CHEAP AS CHIPS

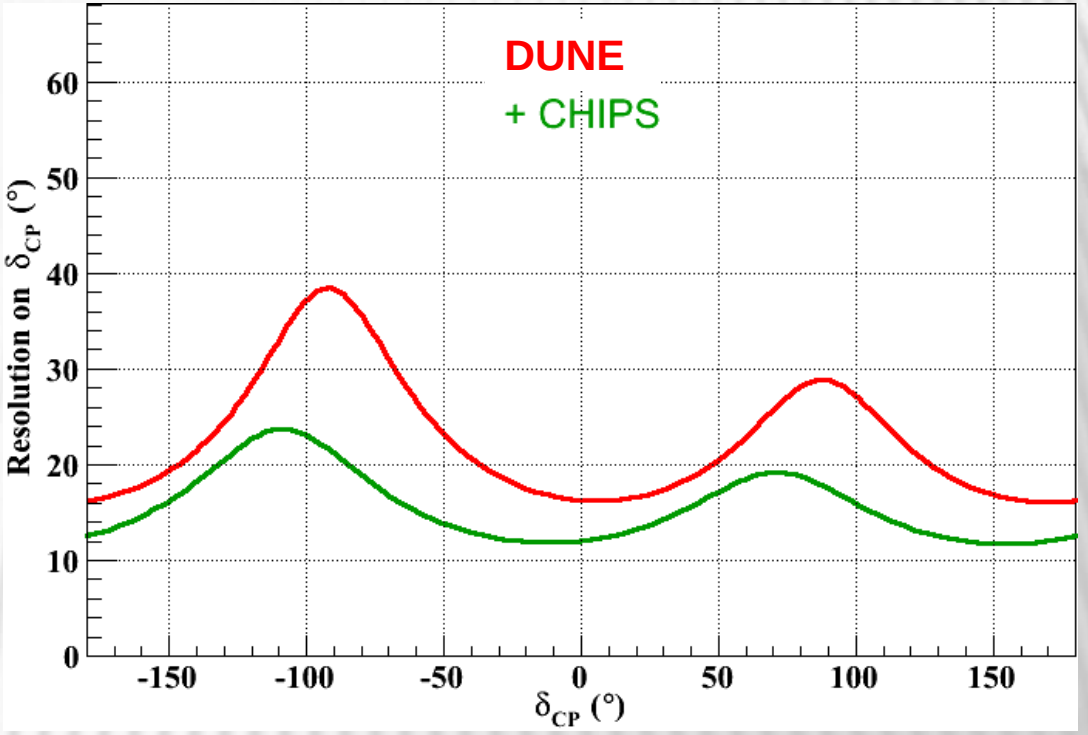
- Large modular detector built underwater
- Use existing water reservoirs for mechanical strength and detector mass
- May be deployed in existing beam lines
- CHIPS R&D program aims to demonstrate detector construction costs below $50M / 100kton

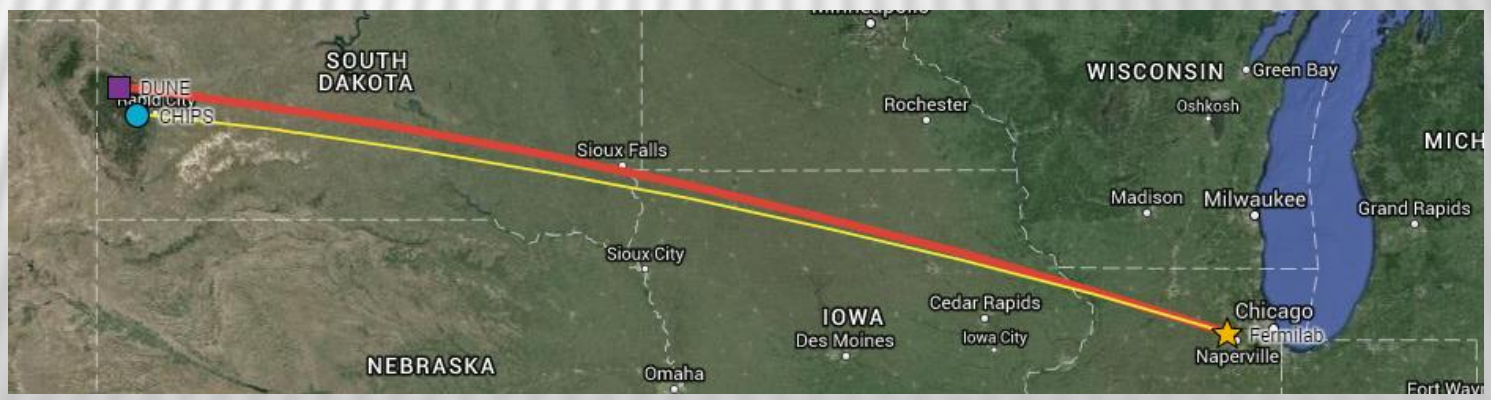




CP PHASE RESOLUTION

- 100kt at DUNE beam line can significantly improve resolution on δ_{CP}
- 6 years of CHIPS at ~20 mrad off-axis
- 10kt DUNE detector





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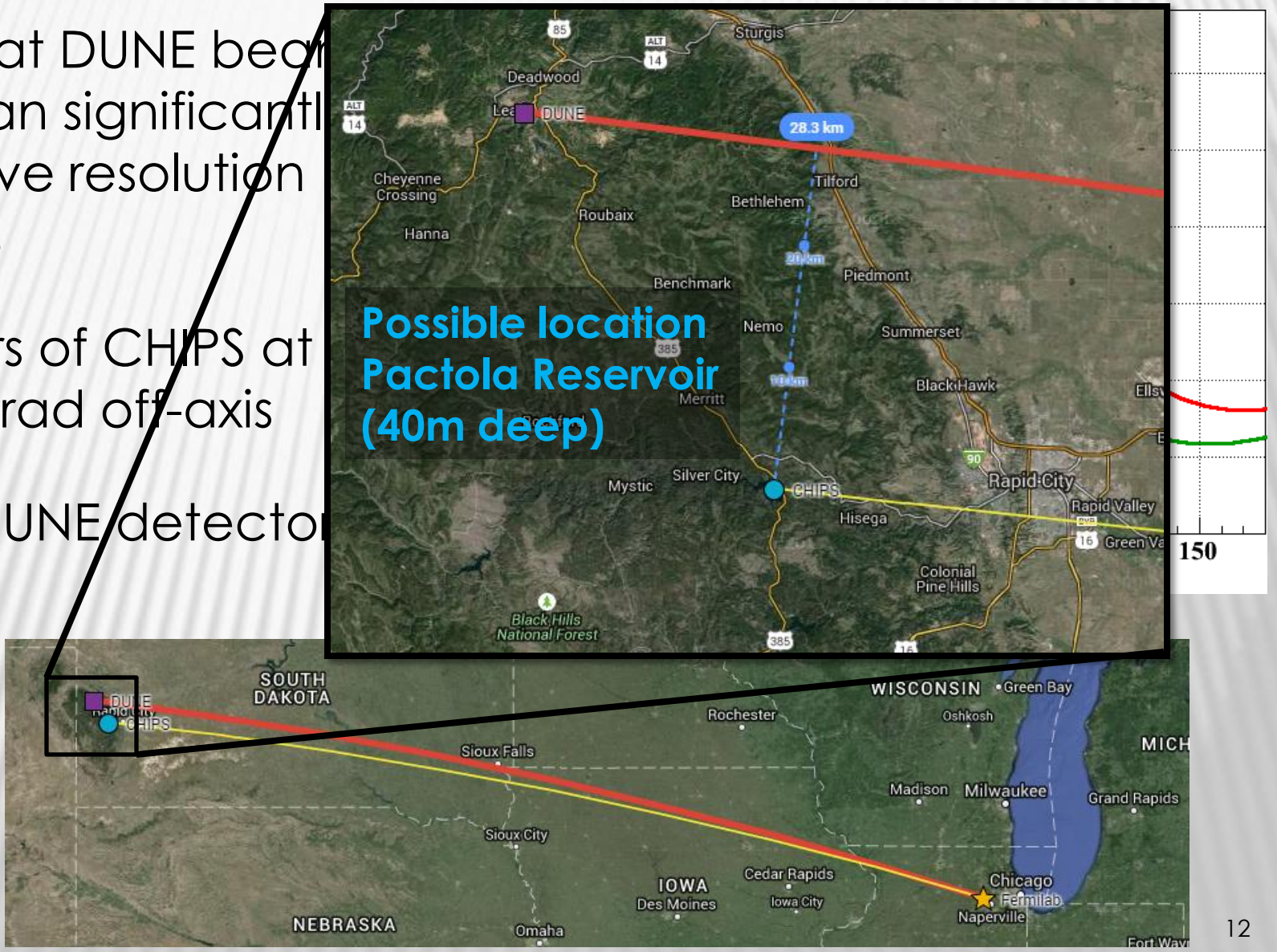
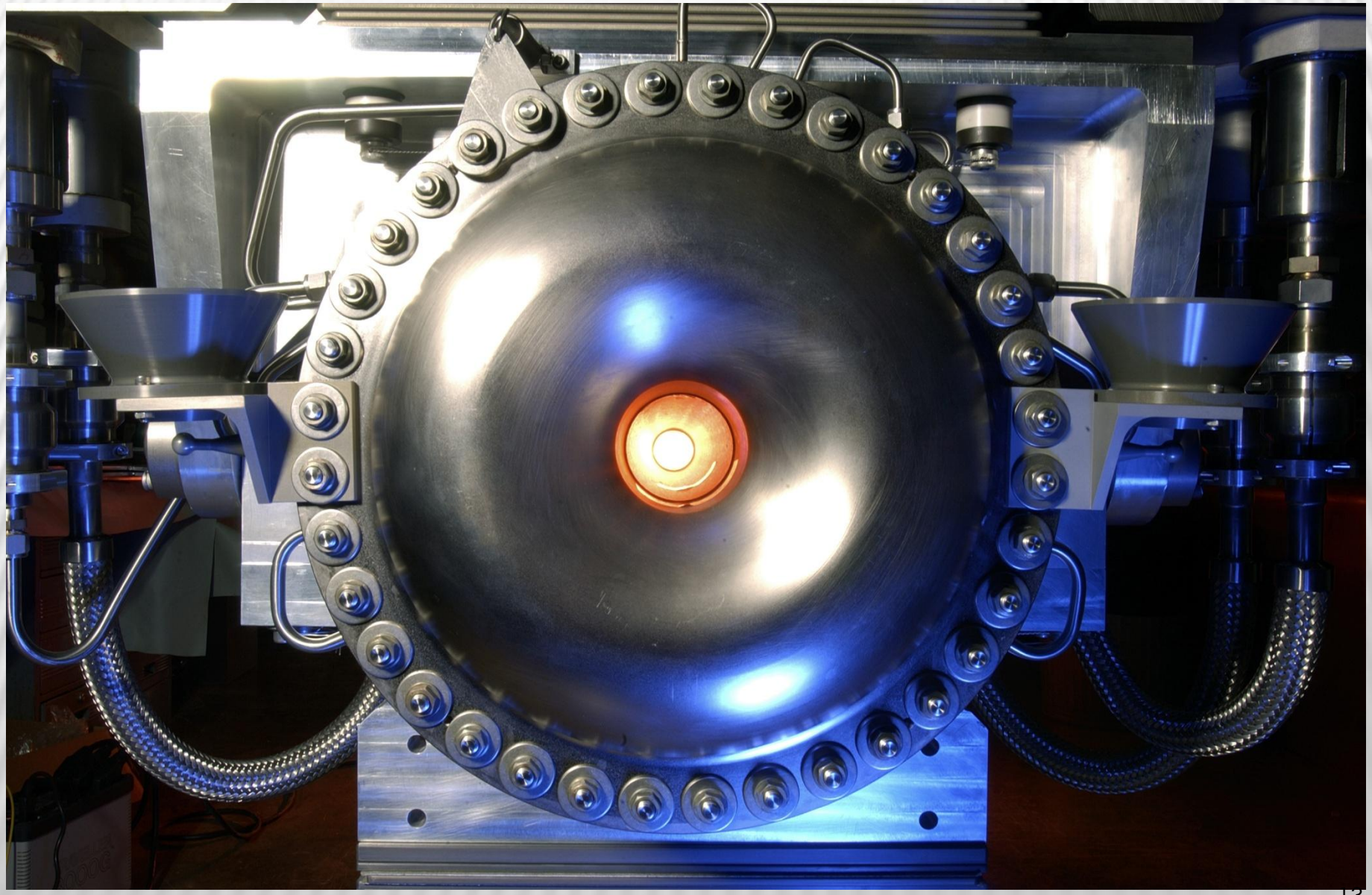
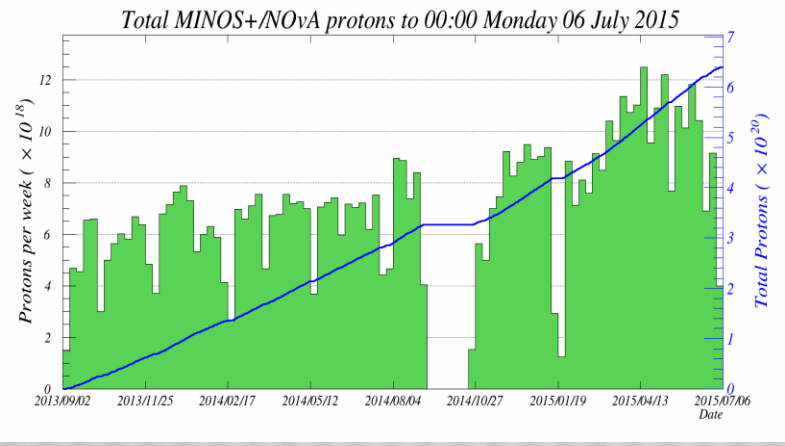


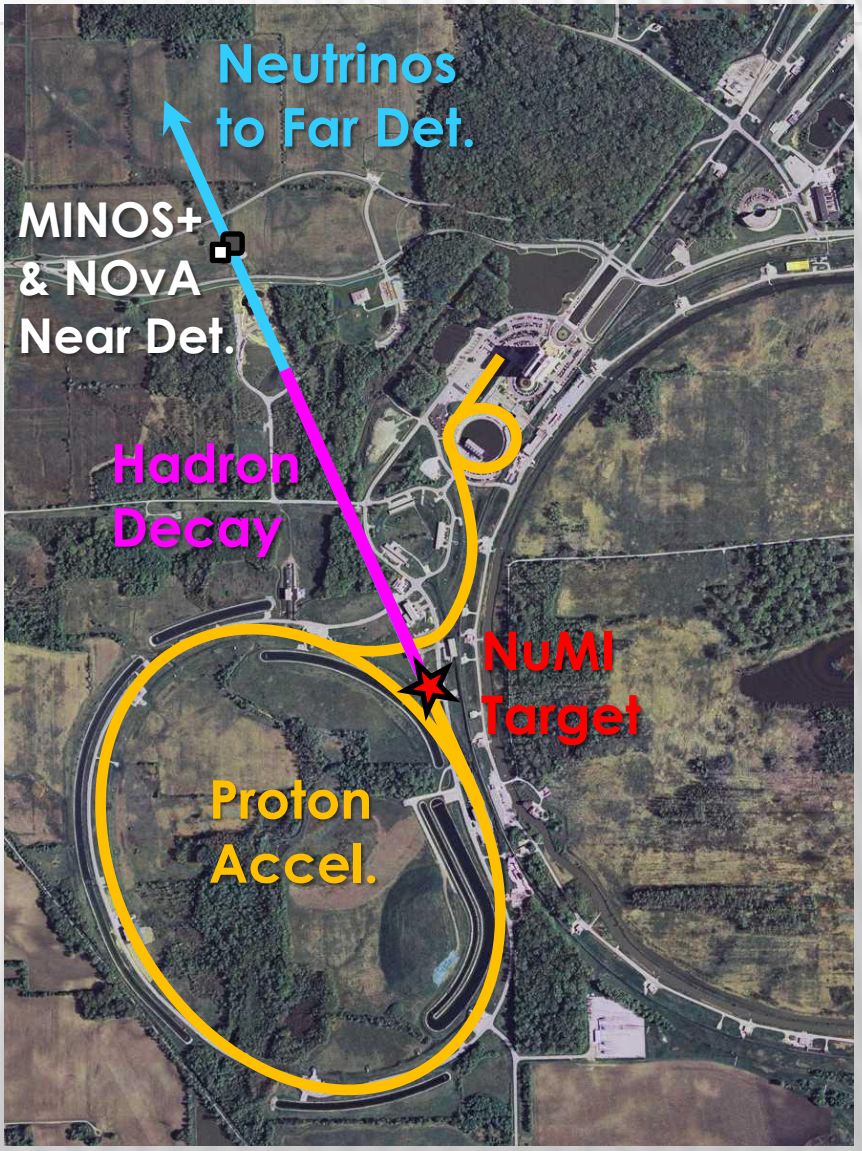
R&D IN NUMI BEAM



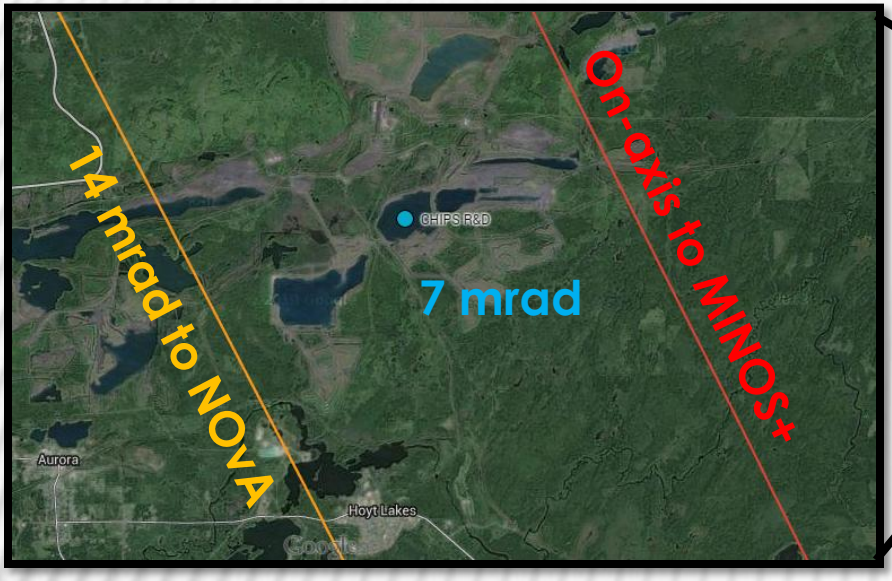
R&D IN NUMI BEAM

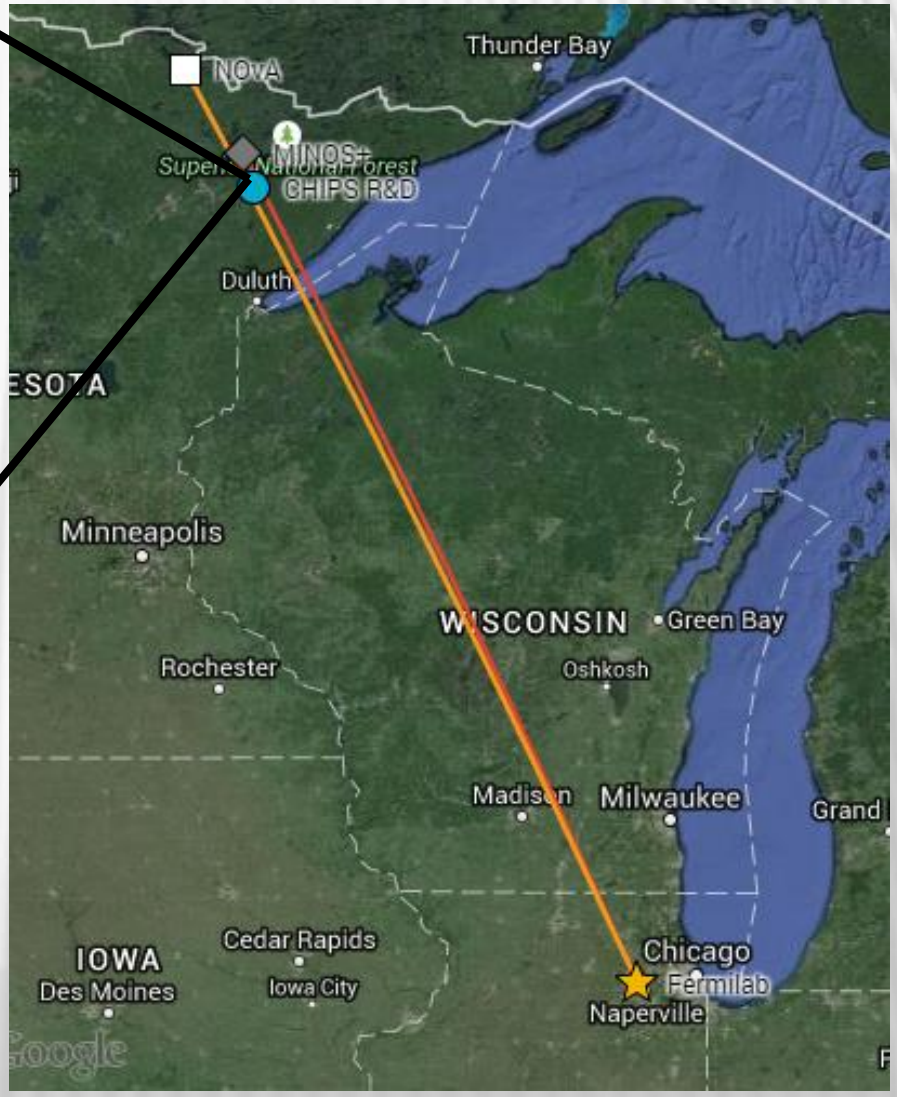
- We have a working beam
- Capable of 700 kW
- Full power by mid 2016
- Excellent opportunity for detector R&D
- Great performance so far

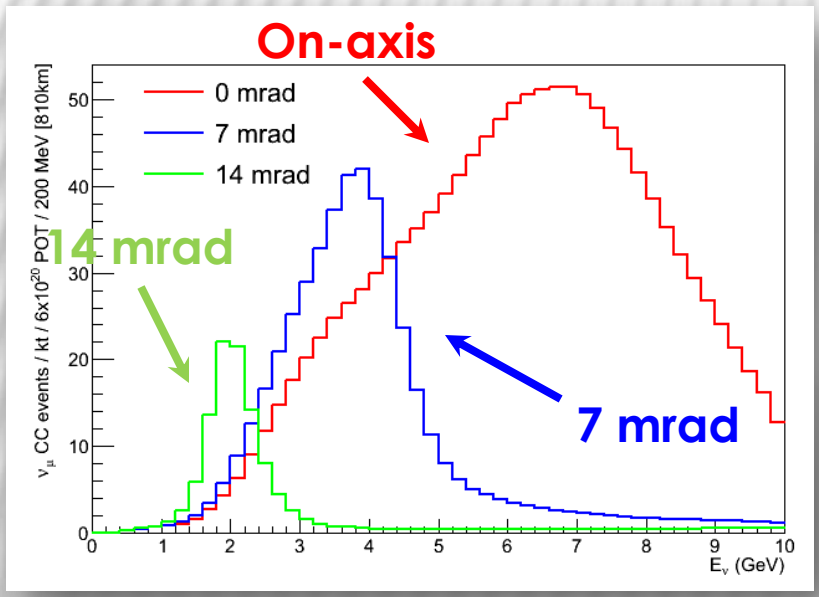




CHIPS R&D LOCATION







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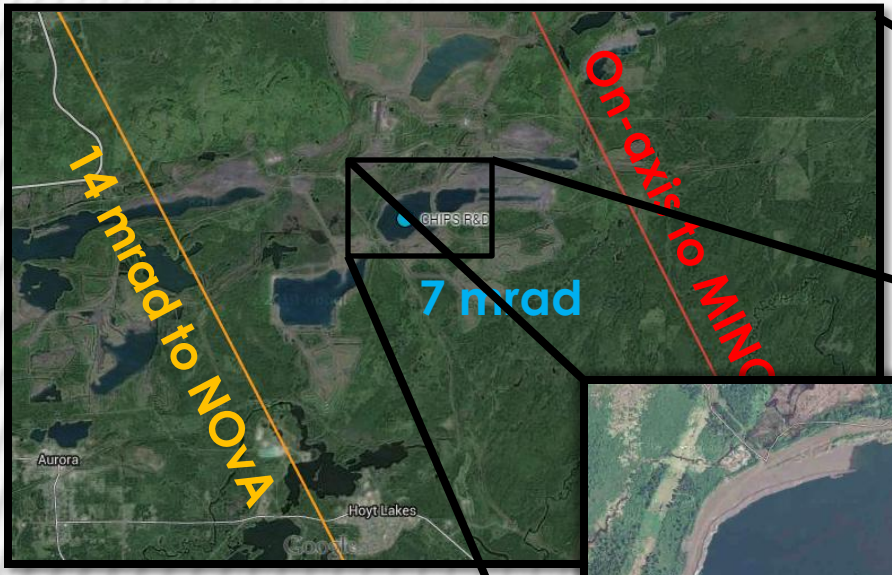

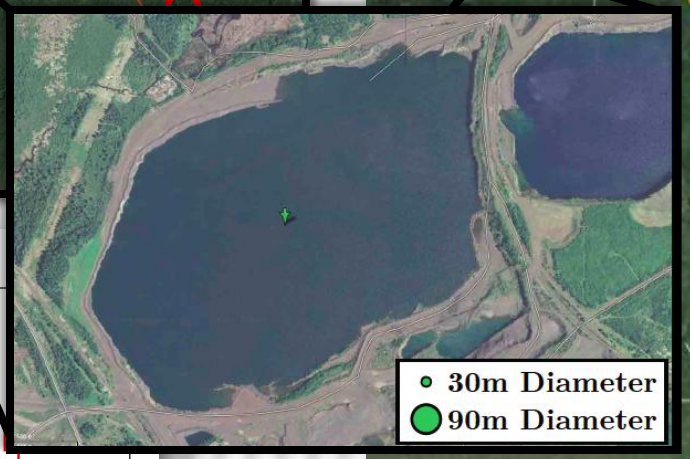

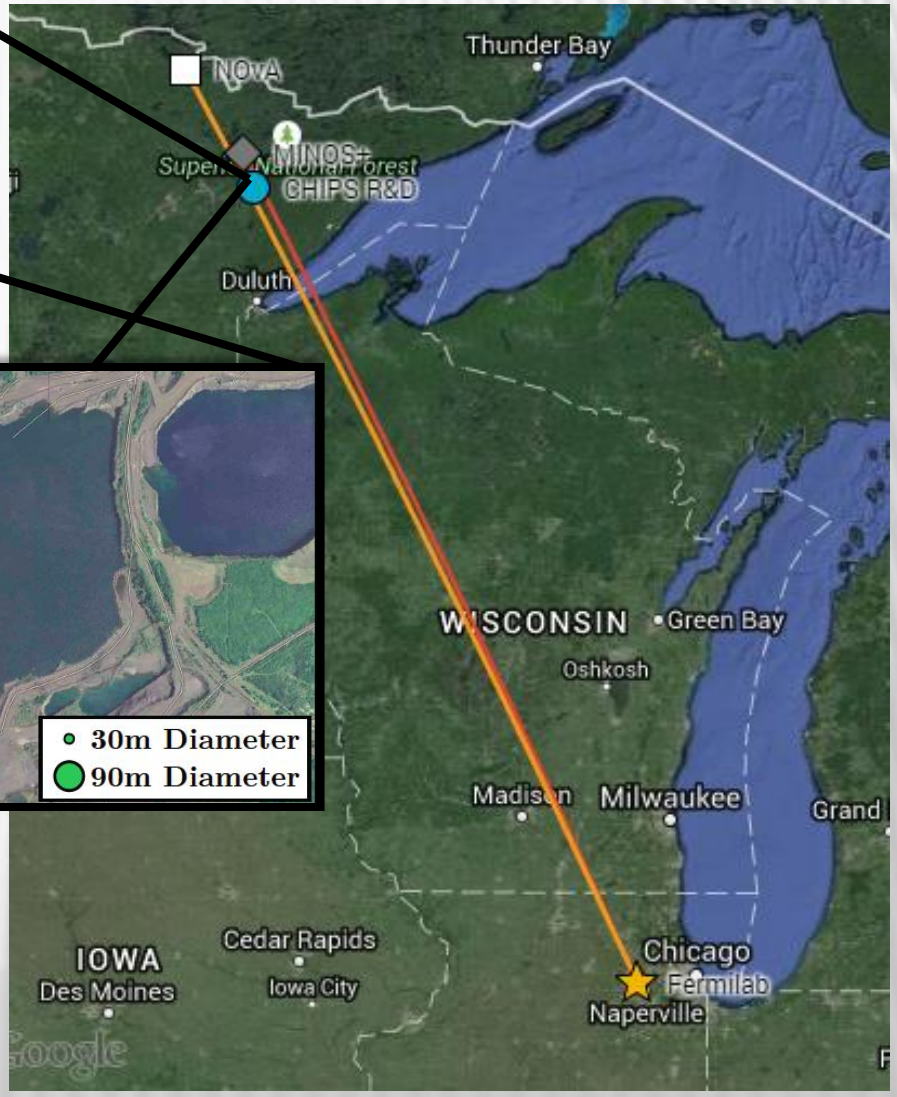

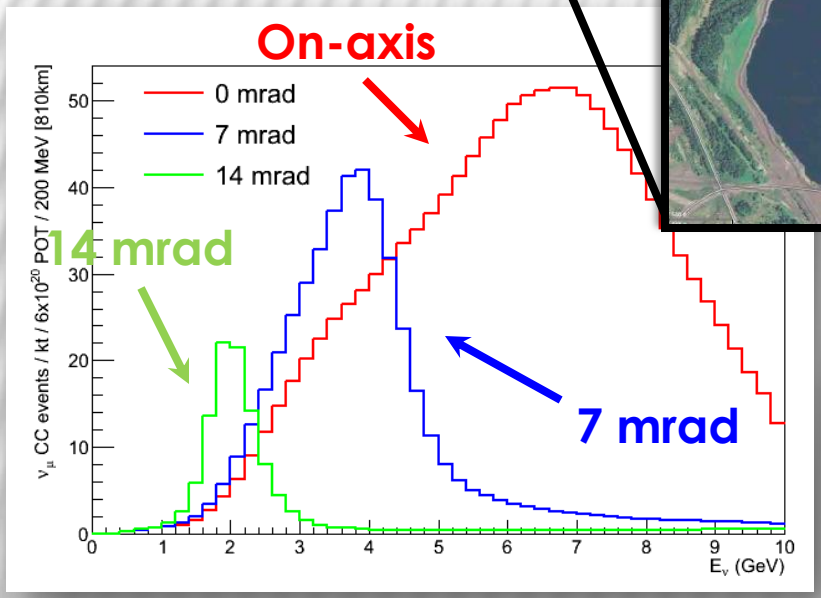

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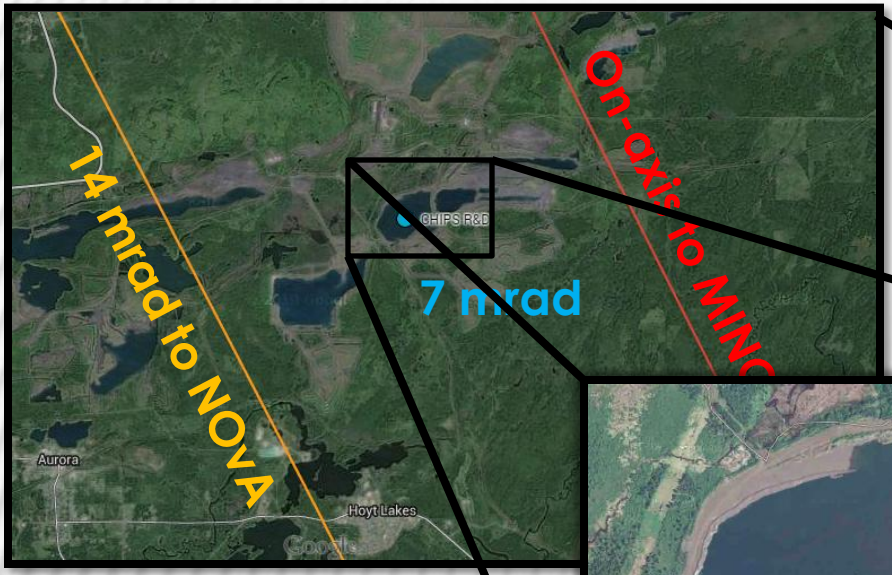
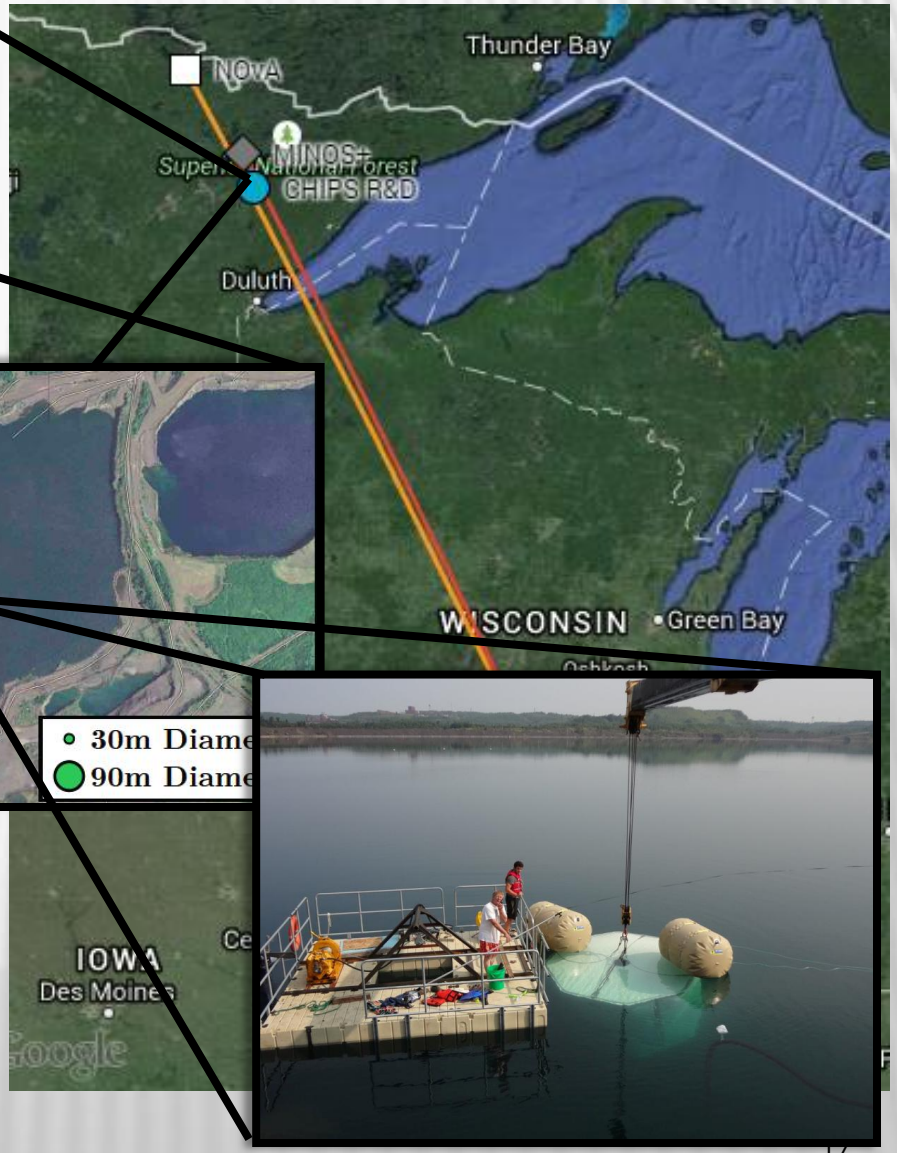
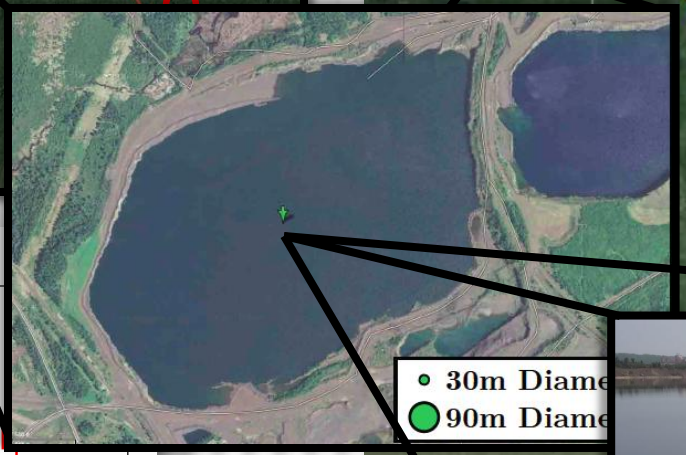
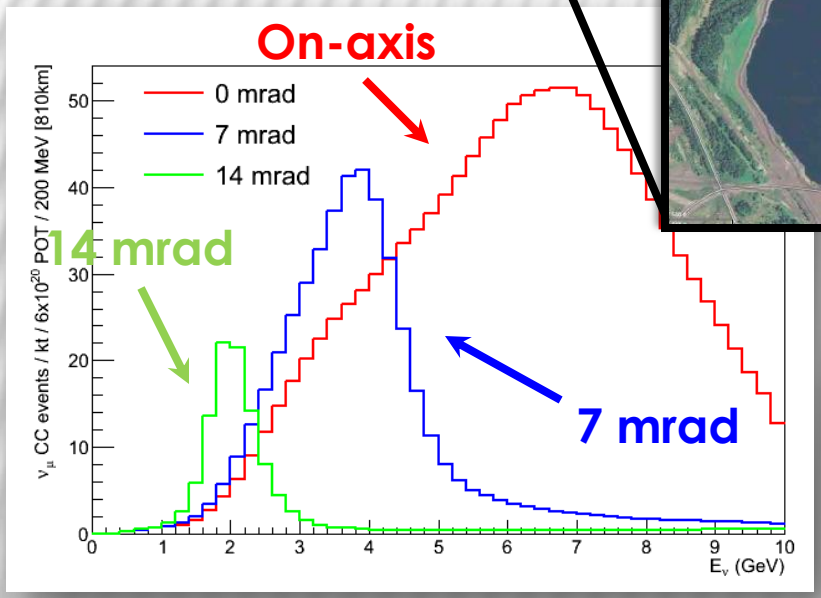




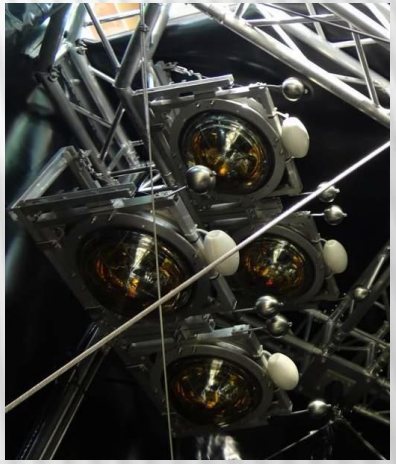


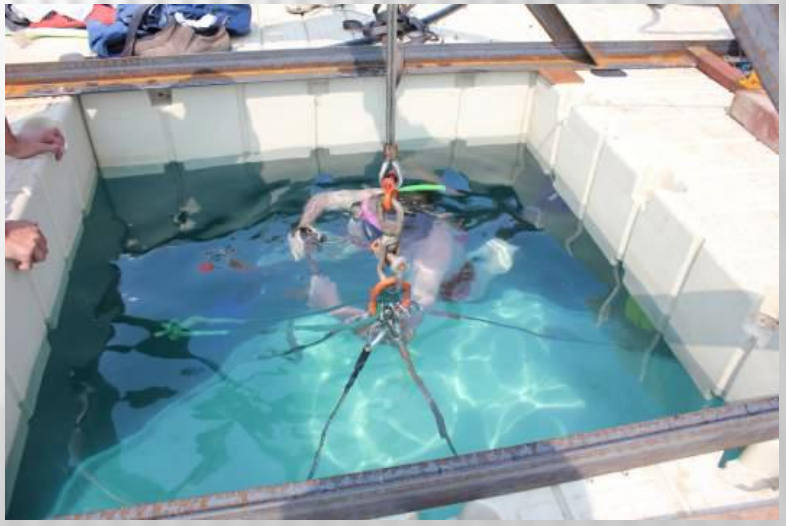


CHIPS-M

- Last summer: deployed 30ton prototype at 60m depth to test durability, filtration system, infrastructure, etc

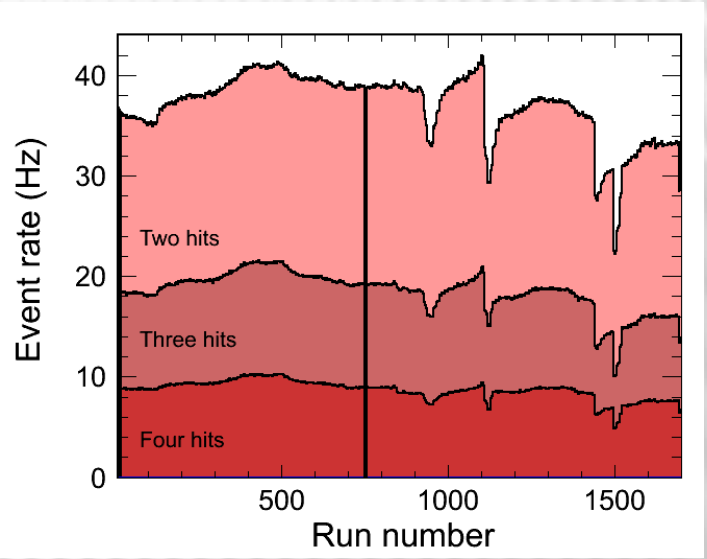
- Instrumented with 5 Ice Cube Digital Optical Modules (DOM)

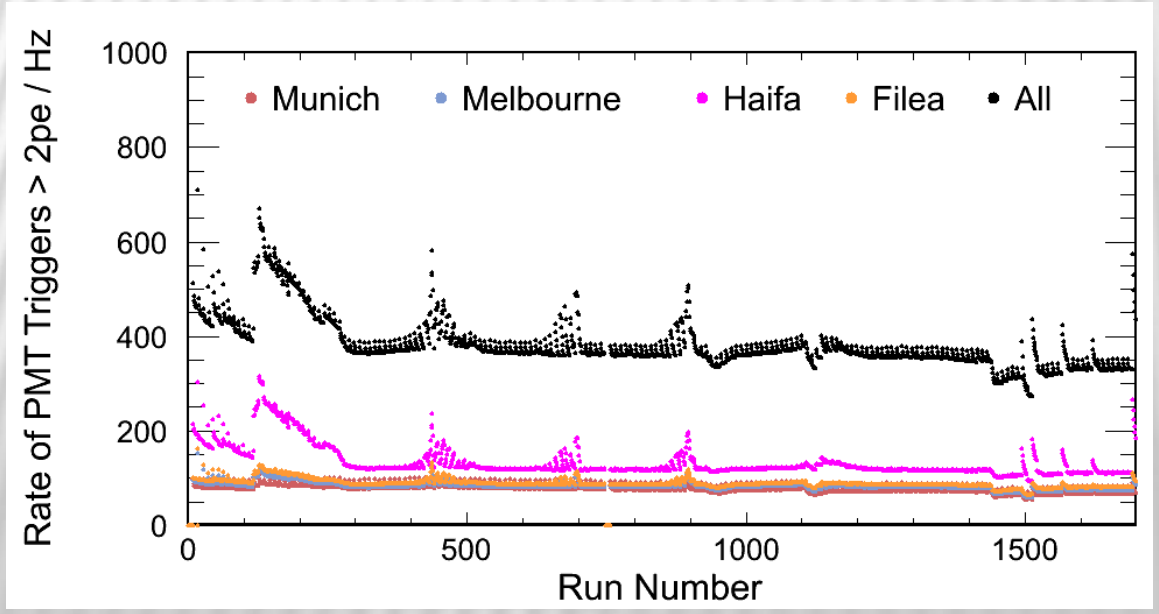




CHIPS-M

- Larger trigger rates correlate with appearance of full moon over the water → Light leak.
- Drop in coincidence rates followed by slow increase correlated with filter changes. Affects water clarity.

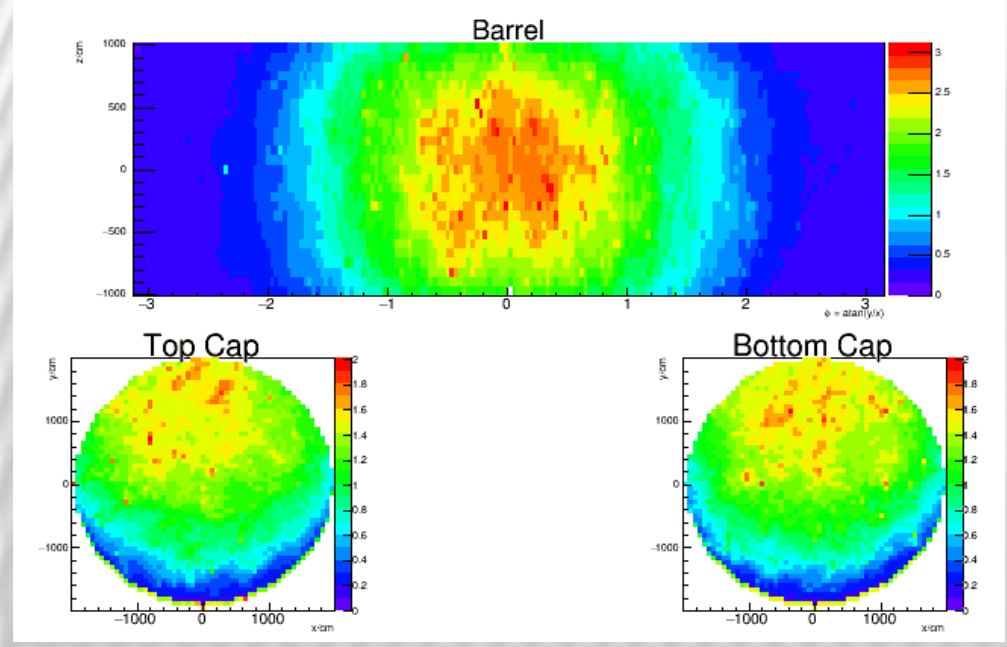


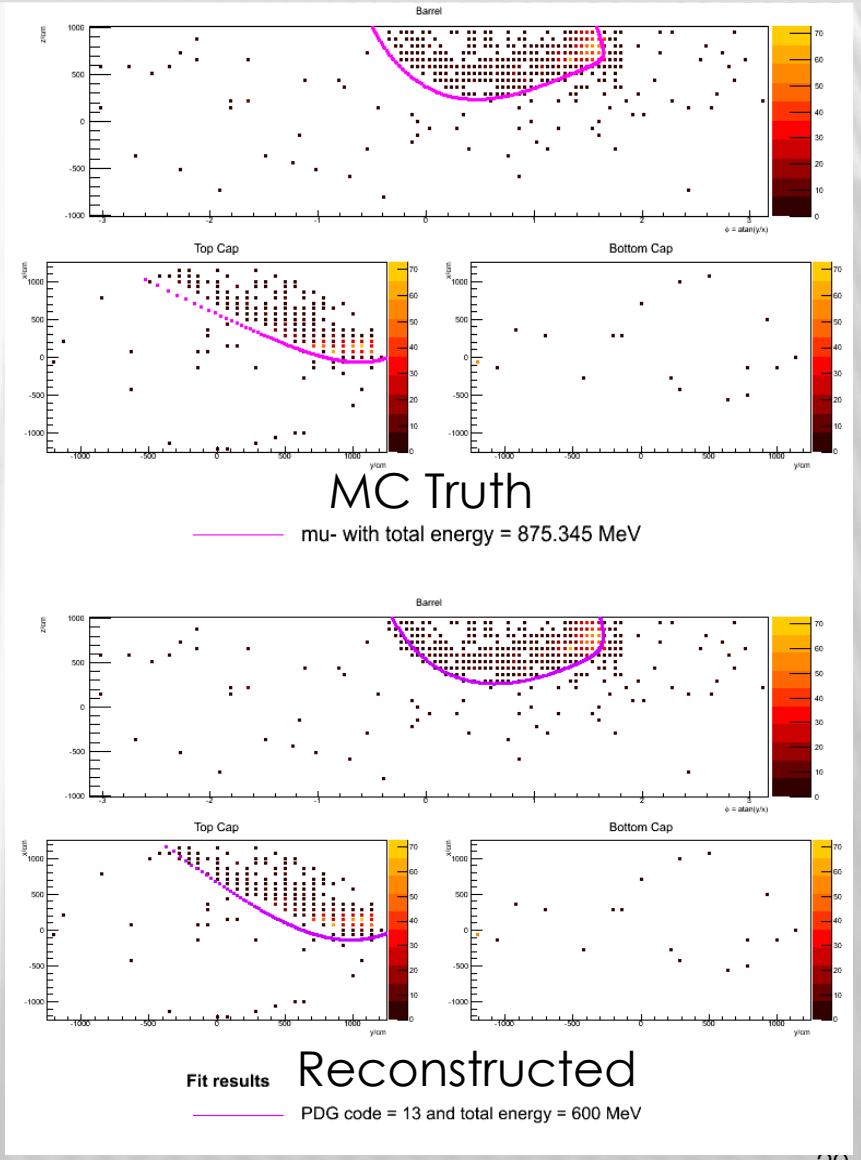


DETECTOR DEVELOPMENT

- WCSim based simlulation
- Reconstruction uses likelihood fits to particle hypotheses. Based on algortihm from MiniBooNE

1000 ν_e-CC events

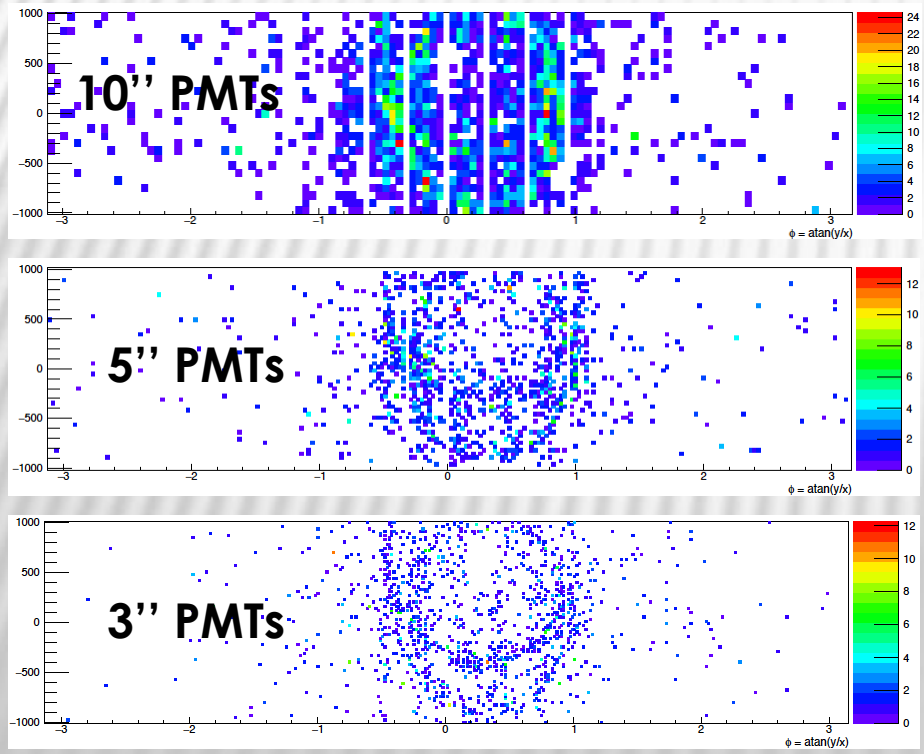


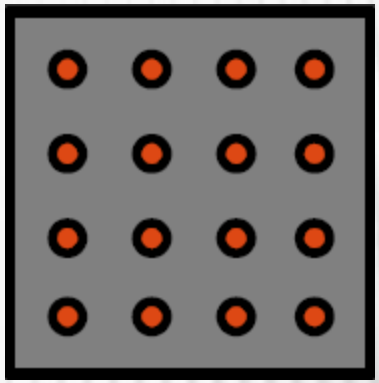


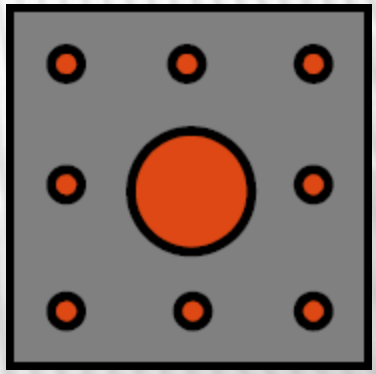
DETECTOR DEVELOPMENT

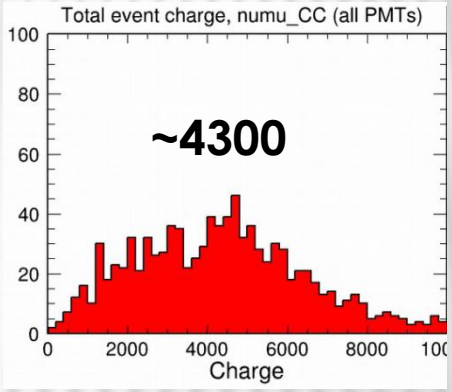
- Optimising PMT layouts
- Considering multiple PMT sizes
- Currently favouring 3'' PMTs using KM3Net DOM ideas

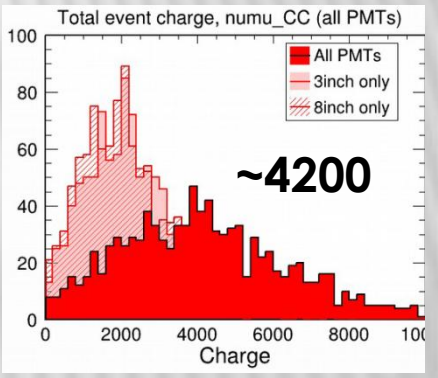
NC π^0 example (10% coverage)

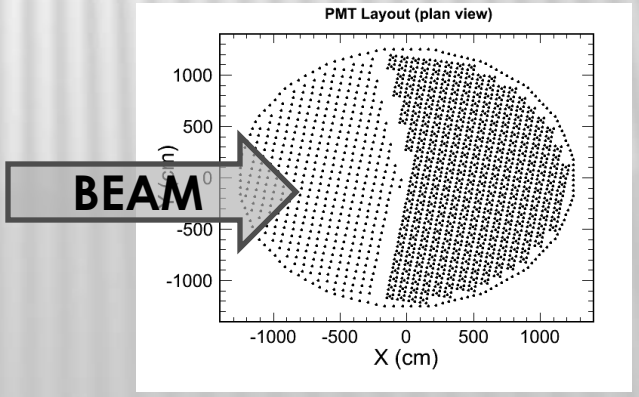










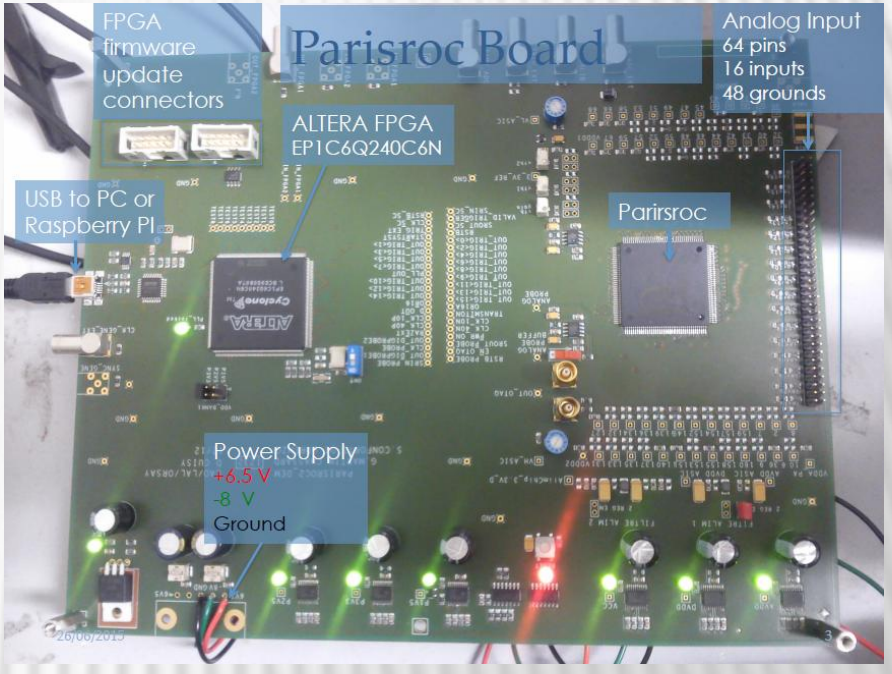


DETECTOR DEVELOPMENT

- Prototype PMT plane built at NIKHEF using 31 3'' PMTs
- 2m x 1m dimensions
- PMTs encased in acrylic hemispheres
- Central readout embedded in aluminium container
- Hardware and PMTs based on developments from KM3Net
- Will be deployed with CHIPS-M this summer (2015)

DETECTOR DEVELOPMENT

- Test integrated readout board with PARISROC chip
- Simultaneous readout of 16 PMTs measuring charge and time
- Used for veto system in outer detector layer with large PMTs
- PMTs will be borrowed from NEMO-3 experiment
- Will also be deployed in CHIPS-M this summer (2015)



SUMMARY

- CHIPS is an R&D project aiming to demonstrate a cheap WC detector concept

- Deployment in the future DUNE beam line can significantly enhance sensitivity to the CP violation phase

- Detector development is under way

- Second phase of prototype being deployed this summer

BACKUP SLIDES